Soil Mineralization Potential as an Indicator of Ecological Disturbance

D. A. Kovacic, A.J. Krzysik. M.P. Wallace, J.J. Duda, D.C. Freeman, J.H. Graham, J.C. Zak, J.M. Emlen, and H.E. Balbach

Nitrogen and Carbon– as biogeochemical indicators

- **N and C dynamics = integrative indicators of ecosystem homeostasis**
  1. **N in the form of nitrate (NO_3^--N) is the first element to leach and often exhibits the greatest losses of all elements following ecosystem disturbance**
  2. **N is the most limiting element for terrestrial plant growth**
  3. **N dynamics are closely linked to C dynamics**
  4. **Carbon levels control inorganic N levels in soils**
     - **C:N > 30 favors immobilization by microflora (decomposers)**
     - **C:N < 30, favors mineralization and inorganic N is available in the soil**

Forest Ecosystems

- **Forests are tight nutrient conservative systems with slow, steady cycling of essential nutrients and slow rates of organic matter decomposition.**
- **Inorganic N predominantly in the form of ammonium - does not leach from the soil and is more energy conservative for plants**
- **High litter fall C:N ratios favor N retention by decomposers and reduce nitrogen availability in soil**
- **Disturbance interrupts NPP (C), increases soil mineralization and results in increased inorganic N (NITRATE) that can readily leach from the system**
  - **Populations of nitrifying bacteria increase under such conditions, and nitrate may become the dominant form of inorganic N present**

Hypothesis:

- **Nitrification potential may be an effective indicator of ecosystem resilience to disturbance (thresholds)**

Objectives:

- Determine if Nitrogen and Carbon dynamics could be used as indicators of ecosystem condition resulting from military training activity
- More specifically – we investigated the roles of mineralization and nitrification potential as biogeochemical indicators of ecosystem integrity

Ft. Benning Site description:

- Soils are highly leached ultisols, low in water holding capacity, nutrients and organic matter w/ high C/N ratios and low total N

  Troup, Ailey, Cowarts Association

  - Sand = 82- 89%
  - Clay = 3.5 – 10.4% at all sites studied
- Highly eroded land due to poor farming practices = loss of nearly all natural vegetation
- 34% of land now planted in pine

Military Training at Ft. Benning includes:

Foot traffic

Bradley M2A3 & M3A3

Light vehicle traffic

Abrams Tank, M1A1 & M1A2

Site Selection Based on a Disjunct Disturbance Gradient

3 sites selected in each disturbance class

High

Current mechanized-in training activities

H3

H1

Medium

Past training activities
Current foot traffic

M3

M1

Low

No military vehicles
Minimal foot traffic

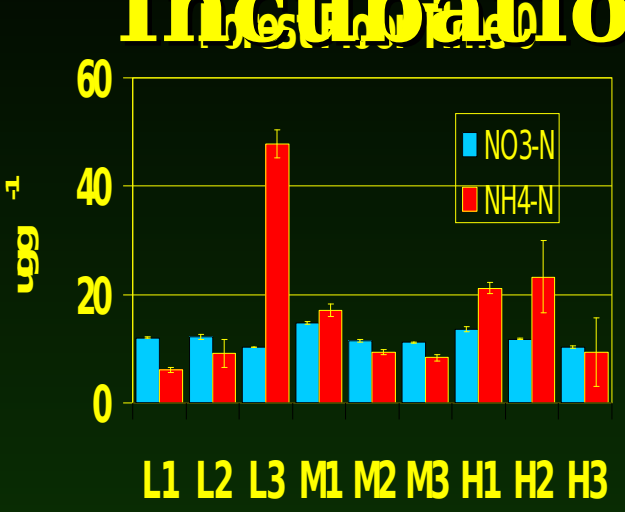
L2

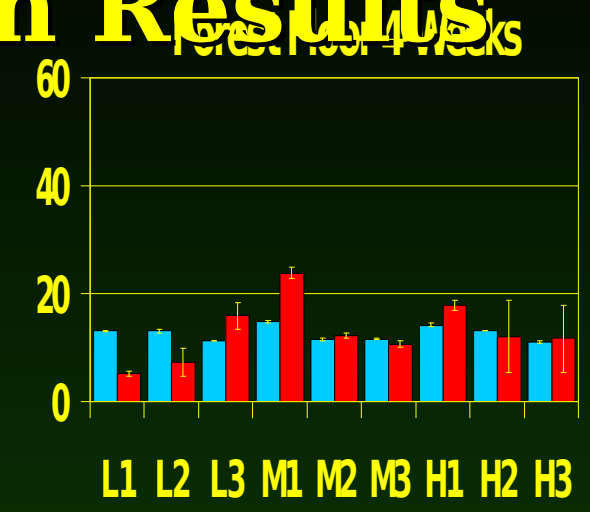
L1

Mineralization Potential Studies

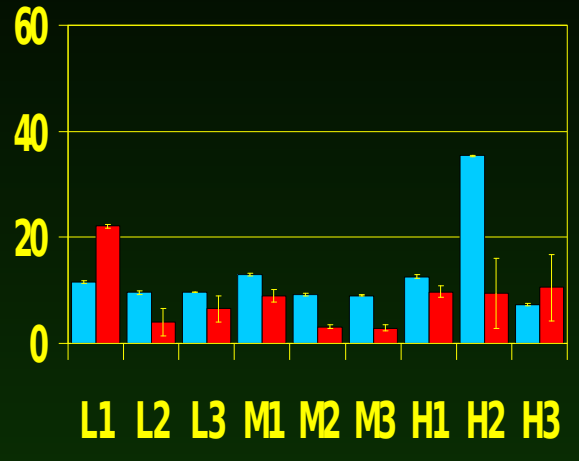
- Forest floor and upper 10cm soil samples collected February 2002
- 5 subsamples of composited forest floor and soil from each of the 9 training sites extracted initially with KCl to determine soil N conditions
- Samples of soil (10g @) and florest floor (3g @) were incubated at room temp for 4 and 8 weeks, water was maintained gravimetrically
- 2 sets (45 samples each) of soil and FF were extracted after incubating one set 4 and one set 8 weeks
- Samples were analyzed for NH_4-N (sodium salicylate method) and NO_3-N (cadmium reduction method) using Bran+Luebbe Analyzer.

Forest Floor and Soil Incubation Results

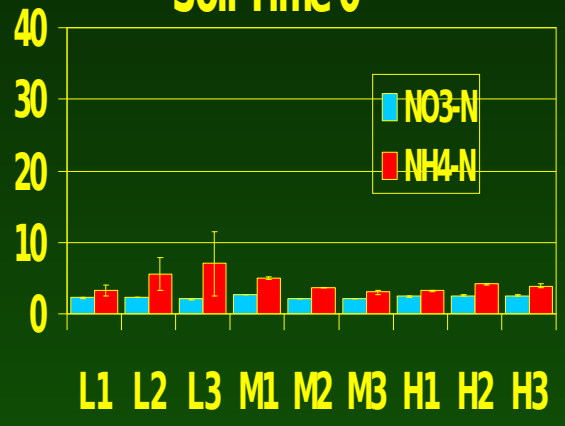




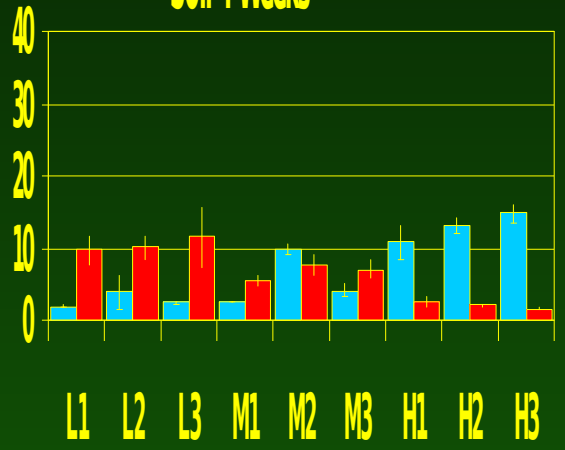
Forest Floor 8-Weeks



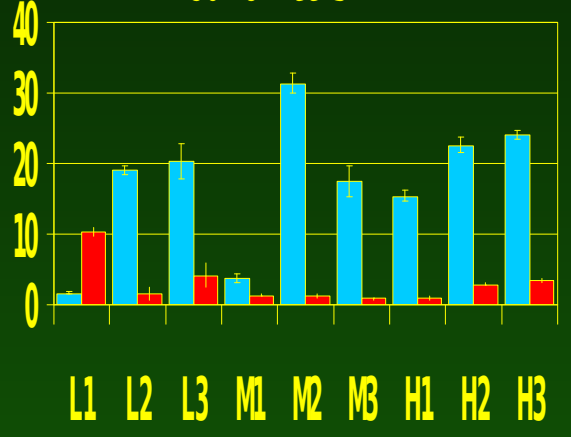
Soil Time 0



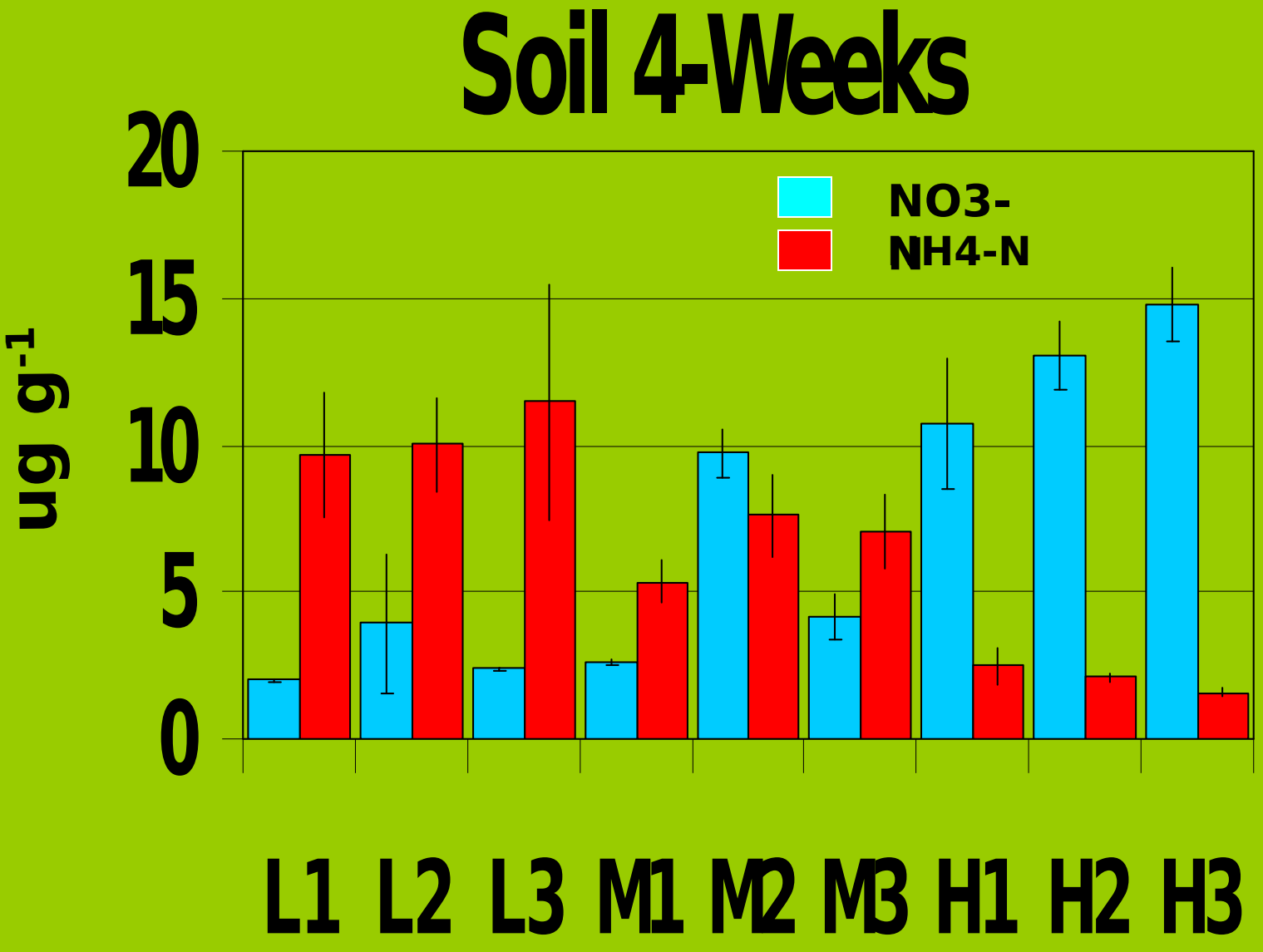
Soil 4-Weeks



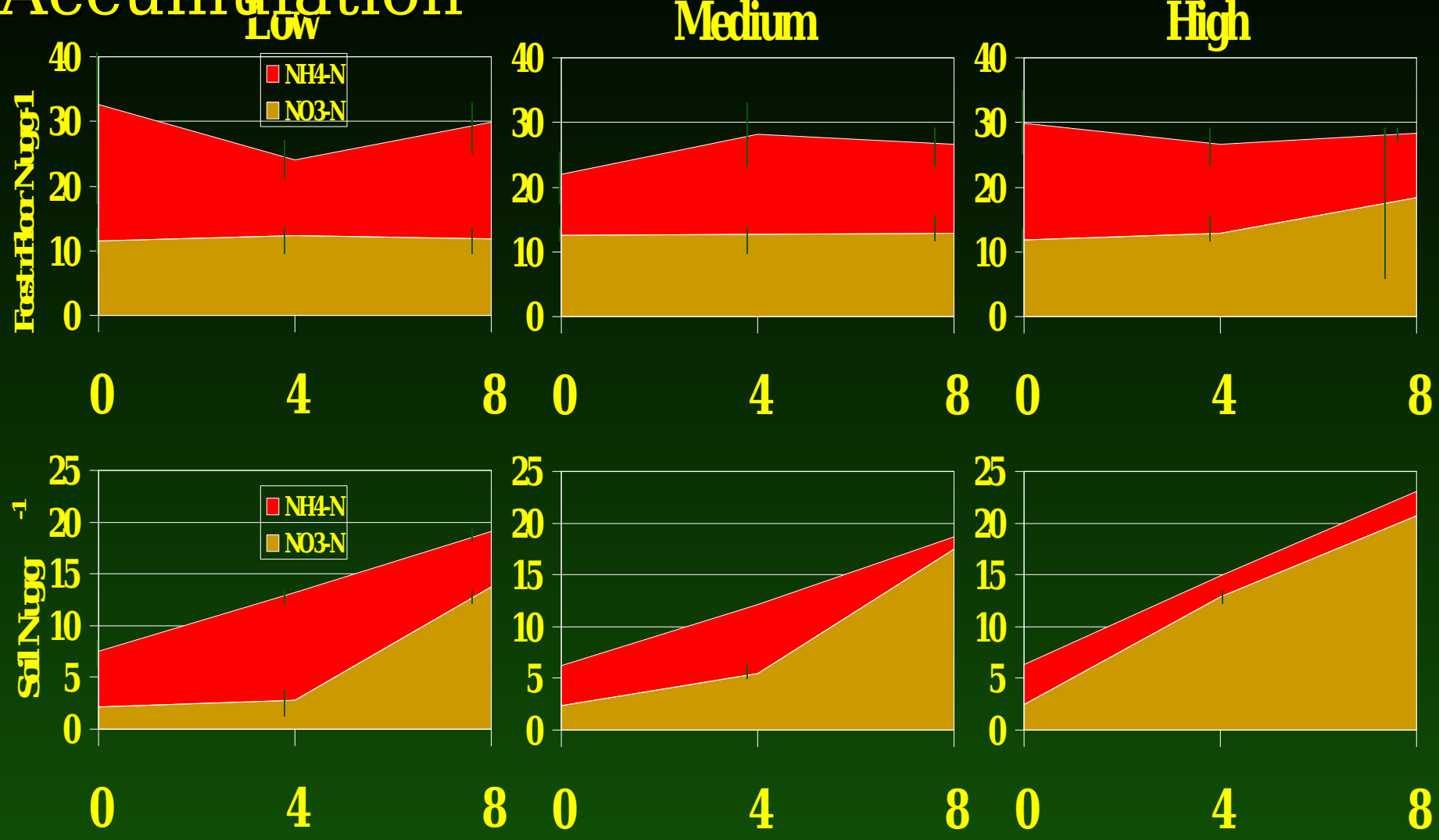
Soil 8-Weeks

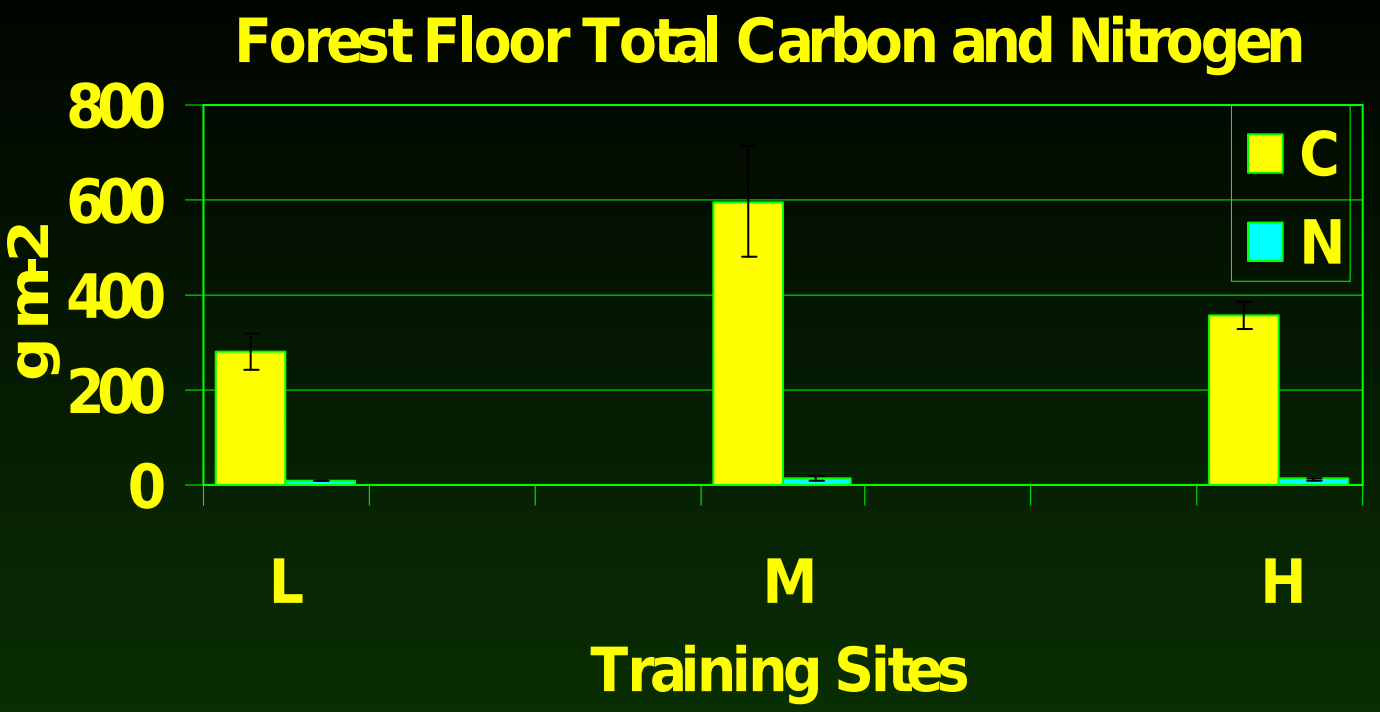


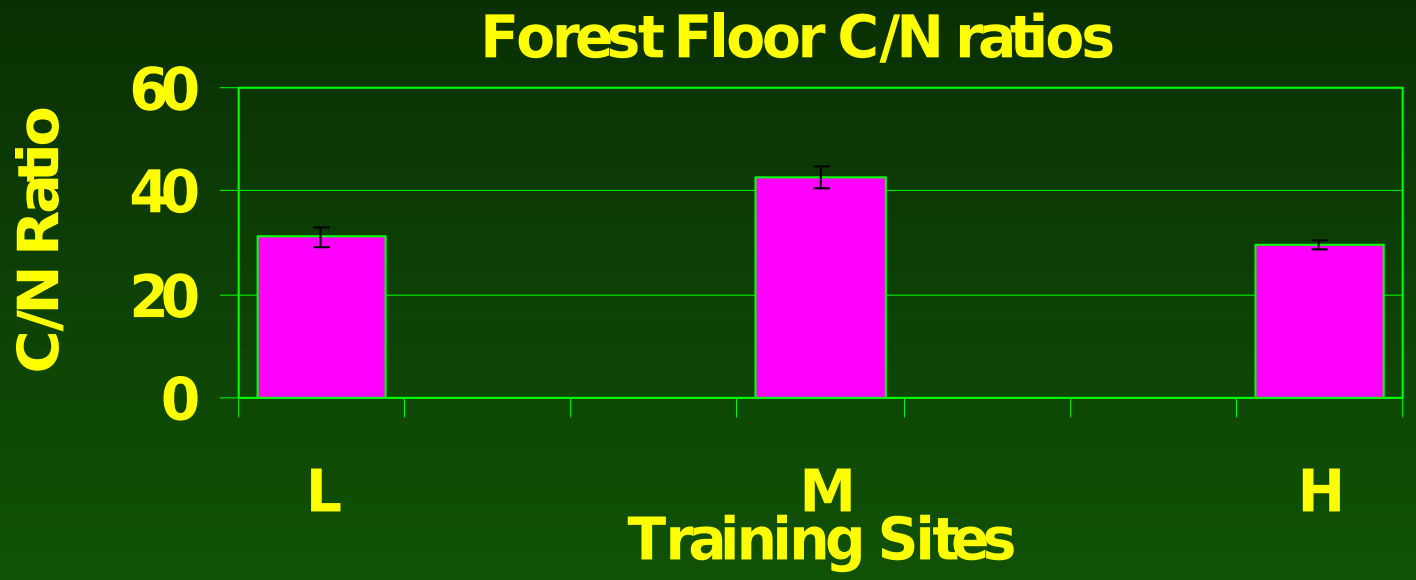
Training Intensity

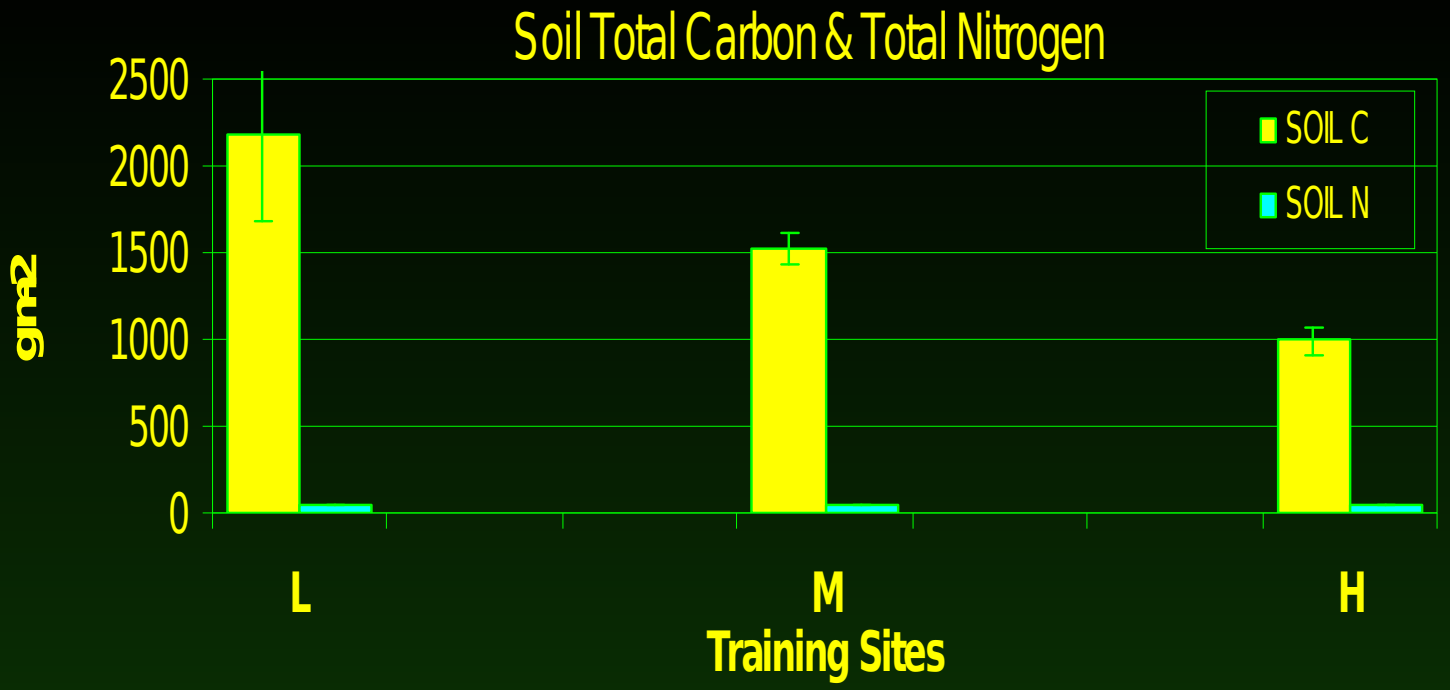

Soil 4-Weeks
20
15
10
5
0
ug g-1
NO3-
NH4-N
L1
L2
L3
M1
M2
M3
H1
H2
H3

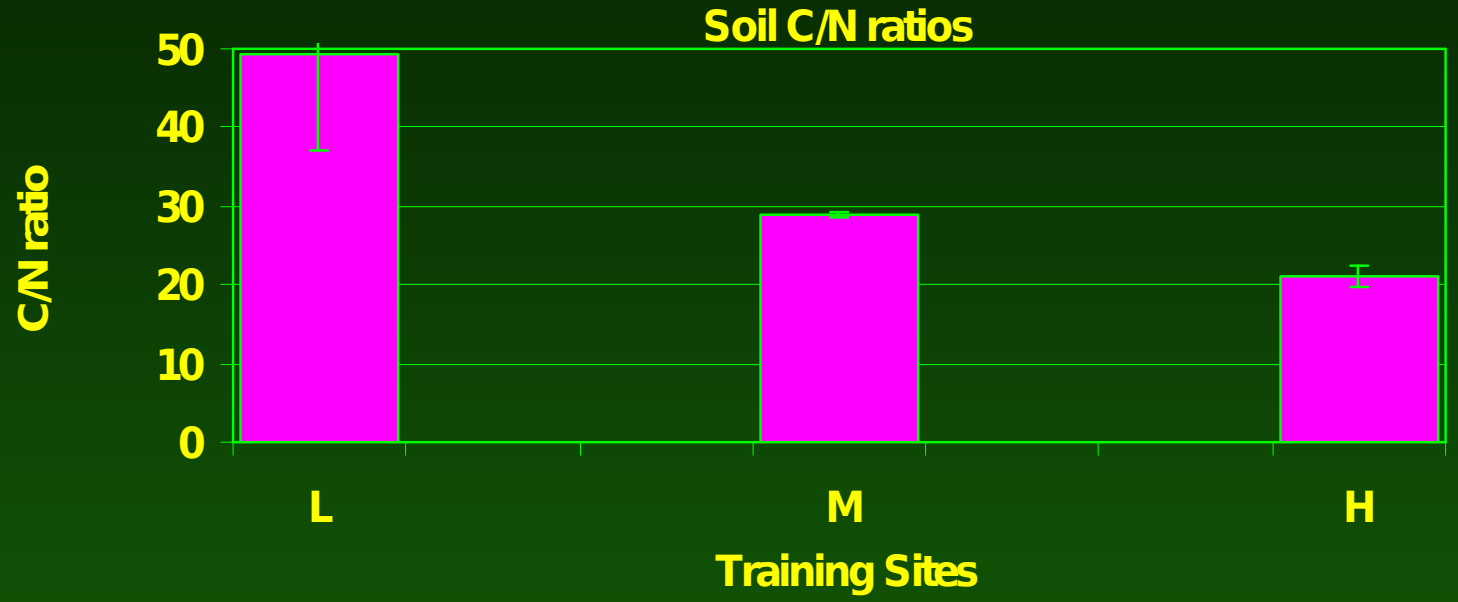
Mean Total Mineralization and Nitrate Accumulation




Forest Floor Total Carbon and Nitrogen
800
600
400
200
0
g m-2
C
N
L
M
H
Training Sites


Forest Floor C/N ratios
60
40
20
0
C/N Ratio
L
M
H
Training Sites


Soil Total Carbon & Total Nitrogen
2500
2000
1500
1000
500
0
gm2
SOIL C
SOIL N
L
M
H
Training Sites


Soil C/N ratios
50
40
30
20
10
0
C/N ratio
L
M
H
Training Sites

What is happening to the environment?

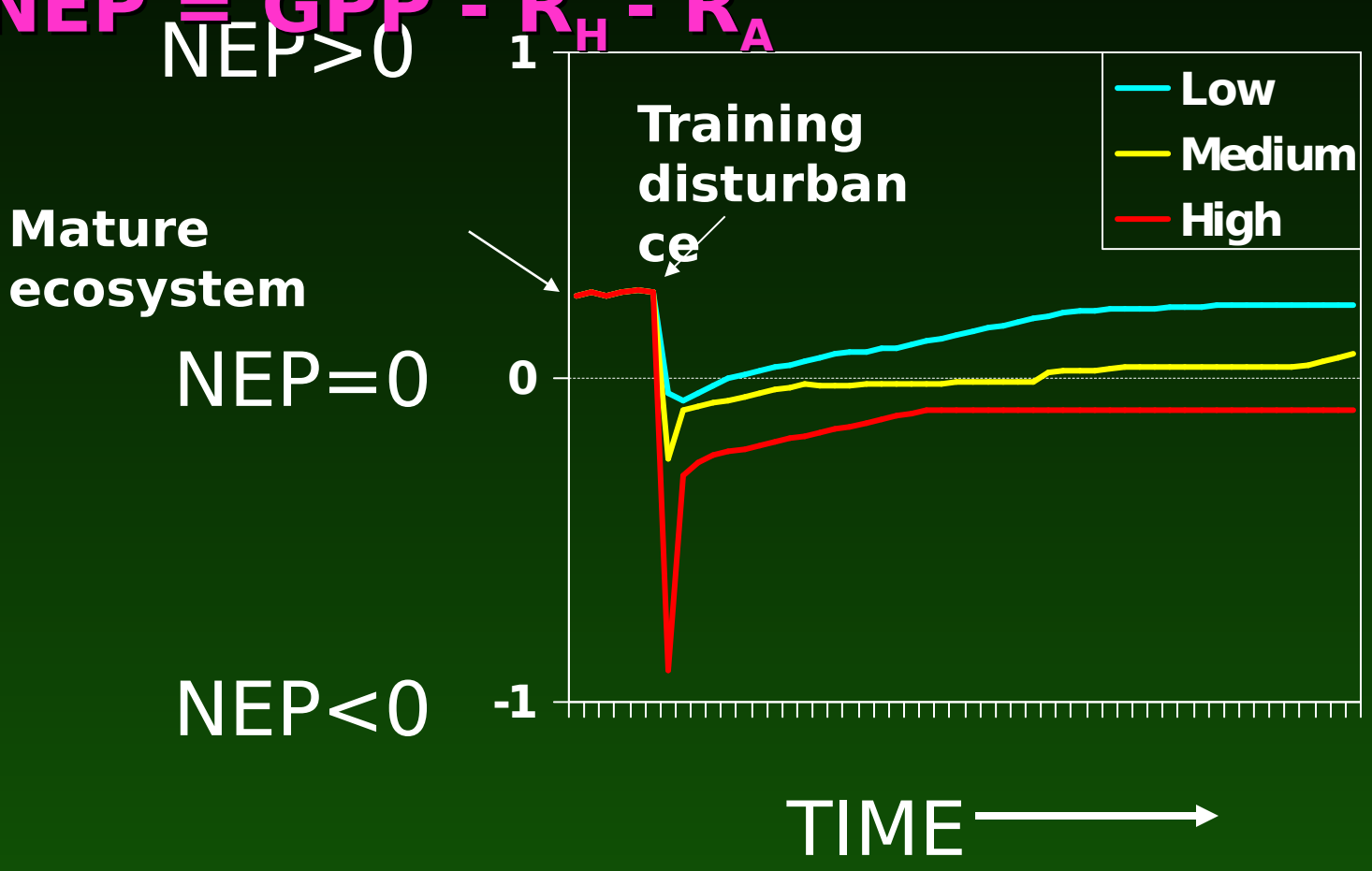
- Landscapes range from less impacted (highly productive) to highly impacted sites
- Impacts = **soil scarification,**
  removal of vegetation,
  compaction
  logging
  prescribed burning
- **Disturbances affect Net Ecosystem Productivity (NEP) and C stores and in turn N dynamics**
- **High disturbance C:N ratios and Nitrification rates in soils**

Why is it happening?

- Organic matter (C) is the keeper of organization in ecosystems (Margalef, 1963)
  - **The amount of biomass (live and dead) that exists is proportional to the influence the ecosystem exerts over future events**
  - **High biomass = high homeostasis = high resistence to disturbance**
-

Hypothetical Net Ecosystem Production plotted as a function of time for low, medium, and high training classes

NEP = GPP - R_H - R_A



Why is it significant?

- Site management should maintain high homeostasis by keeping the system's C and N stocks organized and keeping NEP above zero.
- Less C = less microbial uptake, reduced transpiration, evaporation and shade
  - **Results in increased nutrient mobilization, soil moisture, temperatures that increase mineralization and decomposition, and nitrogen leaching**
- NEP is difficult to measure –
  - **In comparison, soil N and C dynamics are integrative and readily measured indicators of site condition**

Conclusions:

- **Soil nitrification potential appears to be an effective indicator of ecosystem condition**
  - **Results show that low and moderate training sites have resisted disturbance and may be able to withstand similar levels of future training**
  - **Higher level disturbances have exceeded a threshold where NEP is probably negative, rendering areas unsustainable for realistic training missions**
- **Further work is being conducted on an additional 31 sites at FB to determine if our findings hold up across a broader range of sites in the sandhills.**

THE END